Efficient CFRP-Manufacturing Using Multiple Industrial Robots

German Aerospace Center
Institute of Composites Structures and Adaptive Systems

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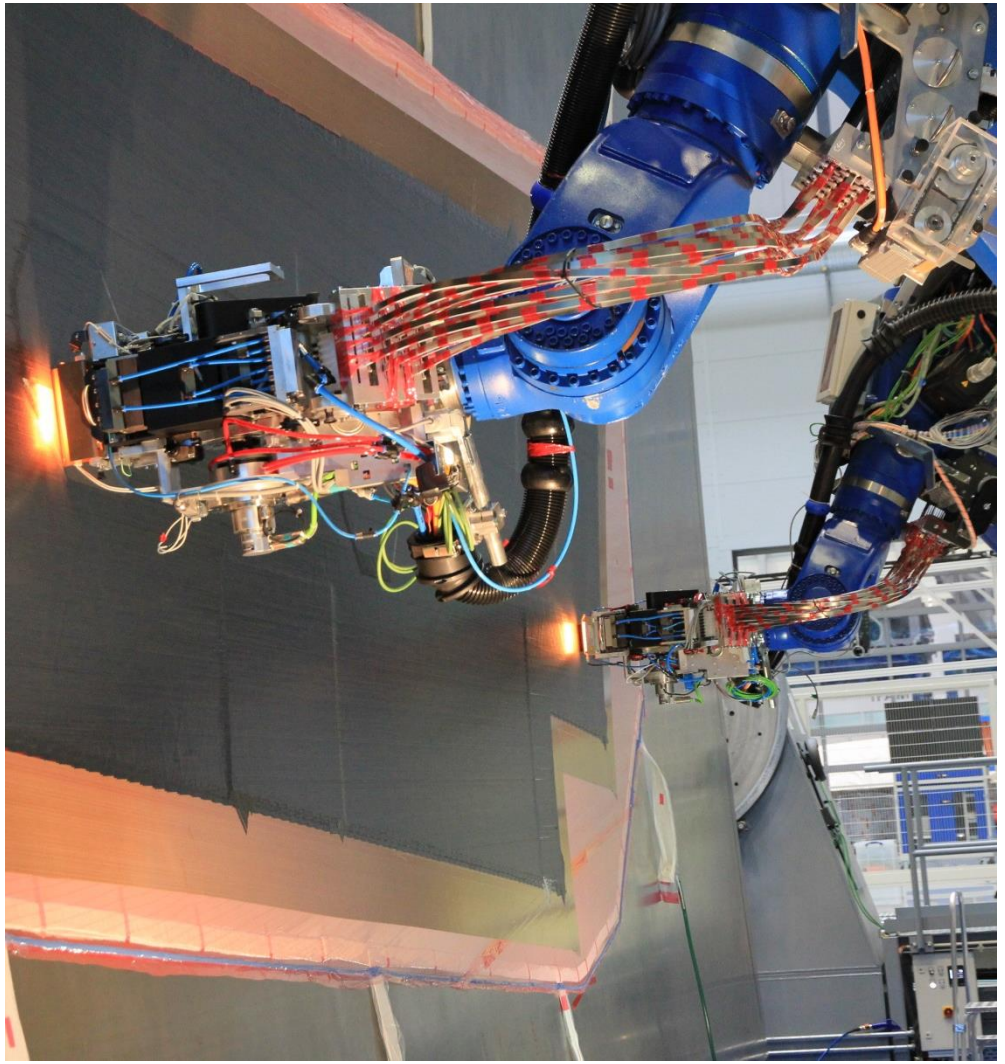
Motivation

Within the project GroFi, the German Aerospace Center (DLR) in Stade developed an innovative plant concept for a fully automated fiber placement (AFP) process using multiple robot units working simultaneously on one or more parts.

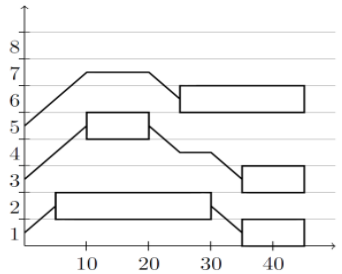
One task of the project EWiMa was the demonstration of a multihead layup with two coordinated fibre placement robots for the first time.



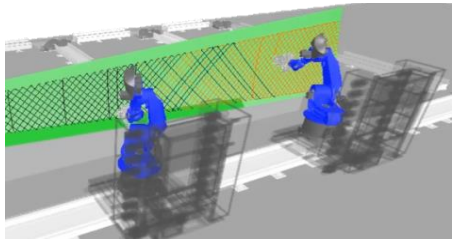
Outline

Development Steps of the DLR MultiHead Approach

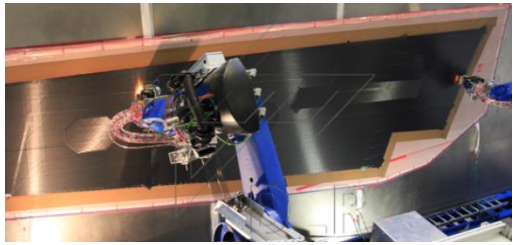
GroFi® Concept



Modelling

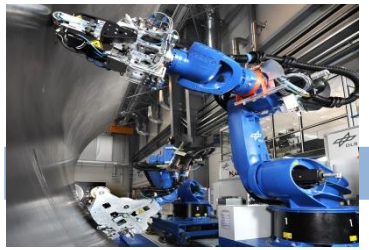


Simulations



Verification

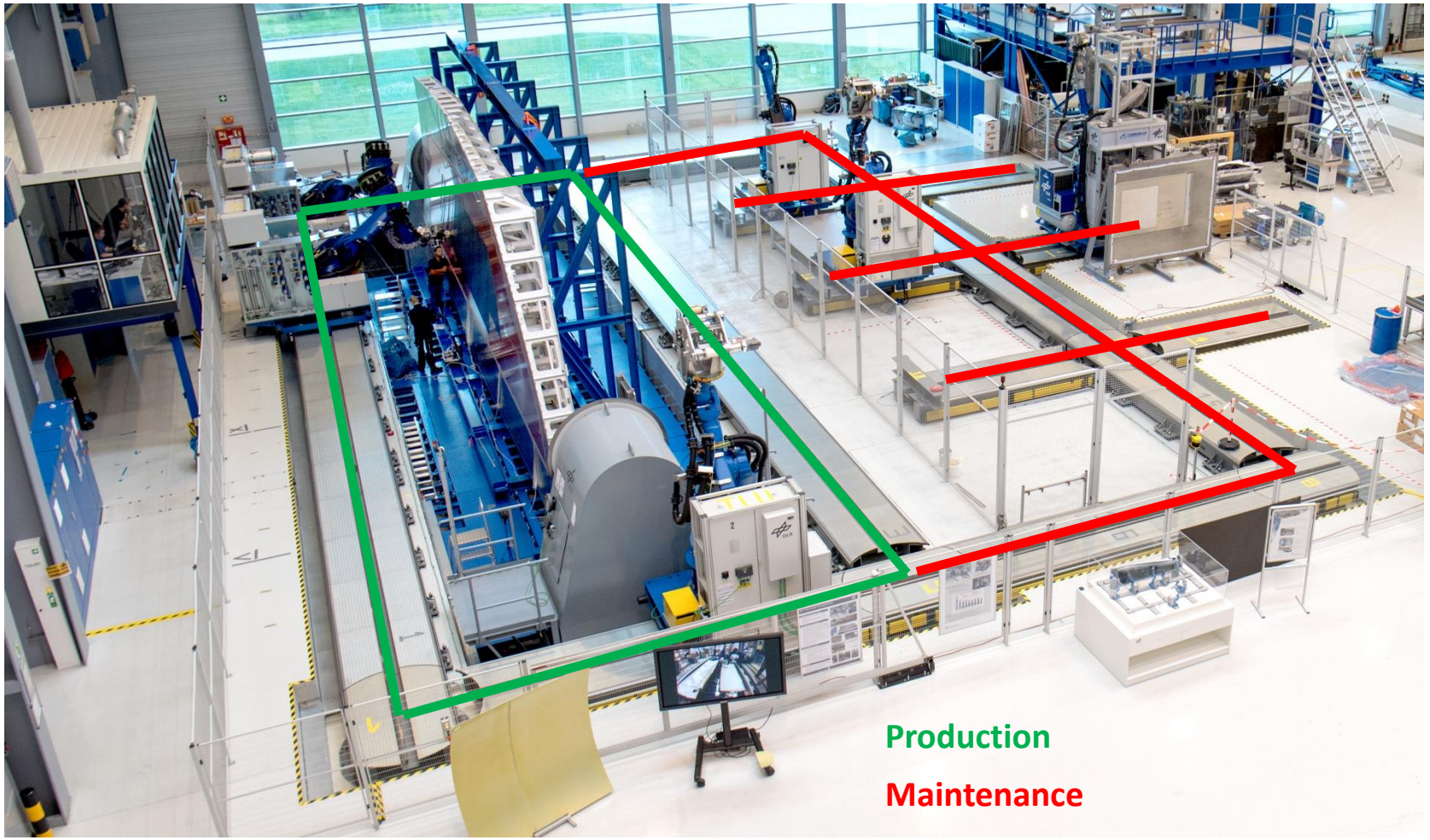
Next Steps



Outlook

DLR MultiHead-Approach

GroFi® Concept



GroFi® Research Platform

- Up to 20m x 5.5m part size
- Up to 8 lay-up units(Kuka KR-500-2 with Siemens Control)
- Seperated production and maintenance area
- Combined usage of different technologies (AFP, ATL & DFP)

Robust | **Flexible**

Cost Eficient | **Time Efficient**

DLR MultiHead-Approach

Modelling

Objective

Collision-free, time optimised coordination of several layup units to increase the productivity of fibreplacement processes

Challenges

- Unique plant concept
- Non-static, overlapping workspaces of the layup units
- No preemption of running tasks

Solution basis: Quay Crane Scheduling Problem

Similarities:

- Rail bounded system (One-dimensional movement)
- Each job can be done by any robot unit
- Precedence constrains between jobs

Deviations:

- Quay crane: no movement during the processing of jobs

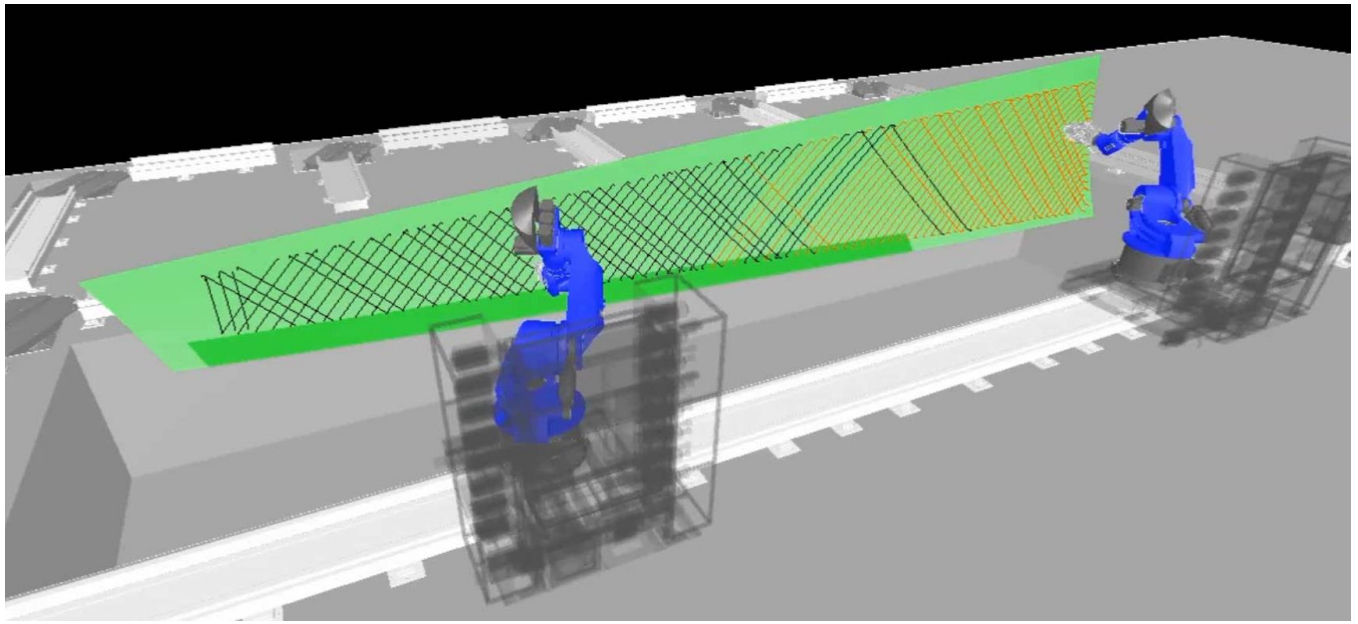
Source: www.konecranes.com

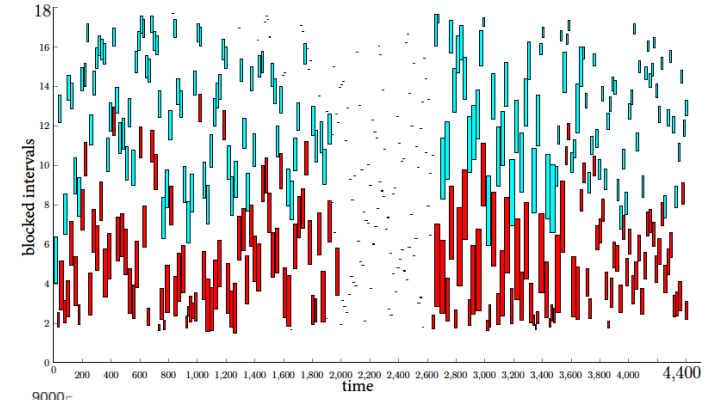
DLR MultiHead-Approach

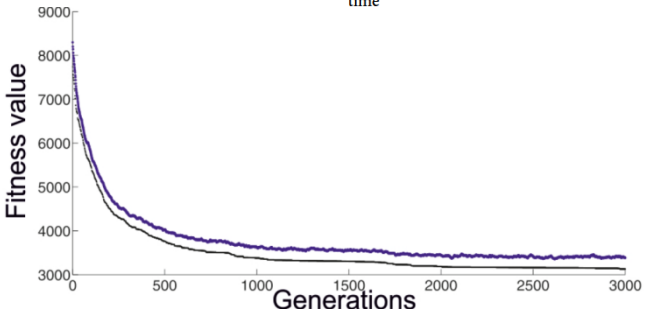
Simulations

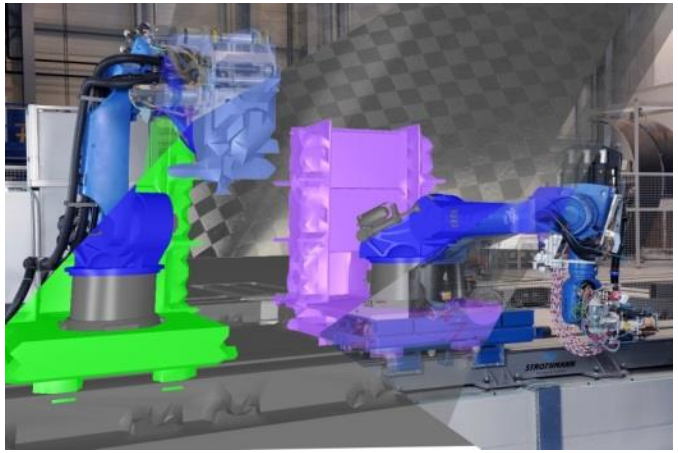
Offline Simulation

Steps:
- Single-Head NC generation (ACE V2.0)
- Kinematik simulation / Time correction (DLR)
- Scheduling (DLR)
- MultiHead-Simulation (DLR + EasyRob)









Online collision control

DLR MultiHead-Approach

Verification – Demonstrator production

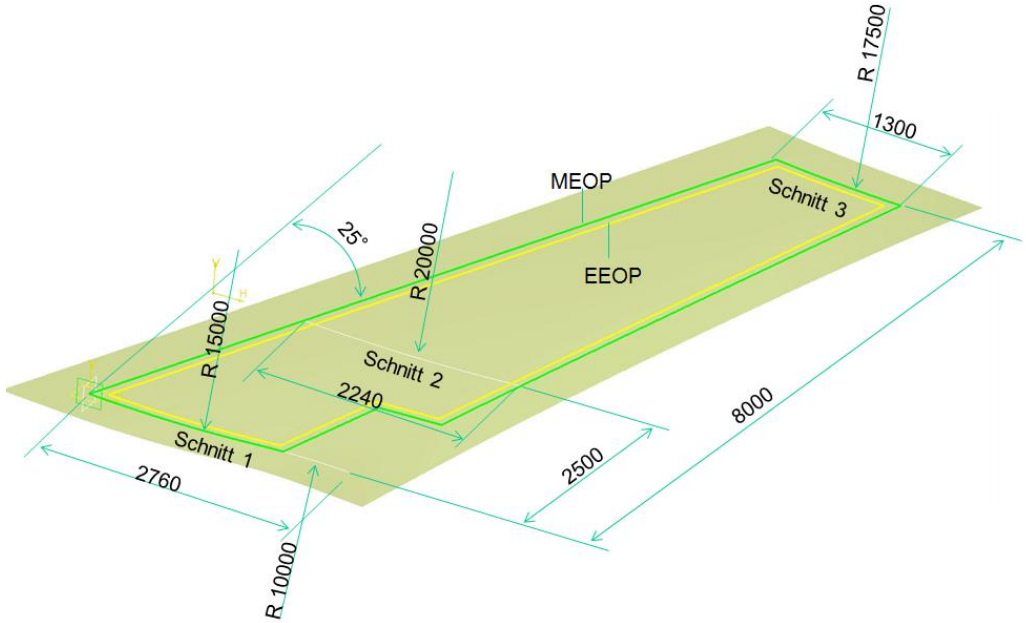
MultiHead Demonstrator (June 2017)

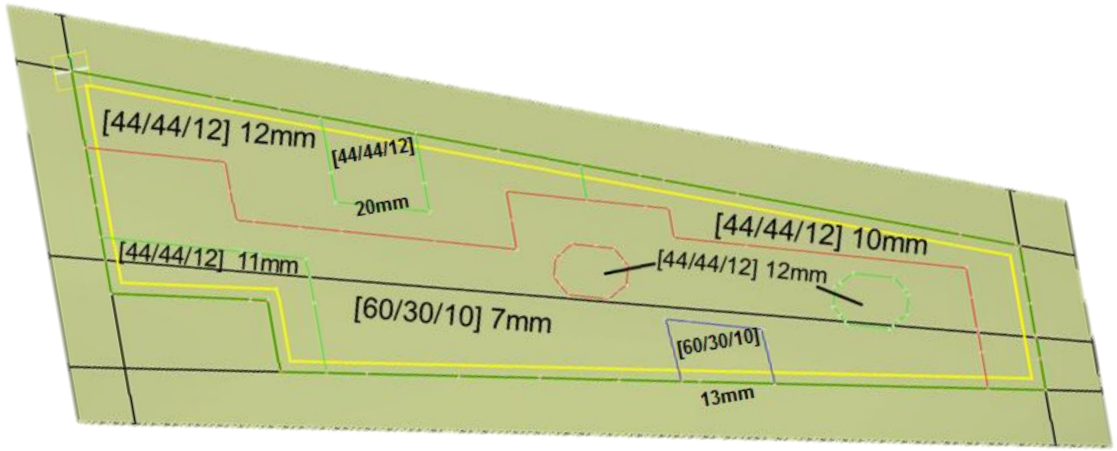
- Generic wing cover design with representative patches and critical features
- 313 plies
- Span 8m
- Maximum Wing Chord 2760mm
- Maximum thickness 20mm (159 plies)
- Use of an Coriolis patent concerning the fiber guidance system

Constraints

- 2 AFP layup units working simultaneously
- Manufacturing pauses during particular evasive movements
  -> additional safety for the first multi-head demonstration

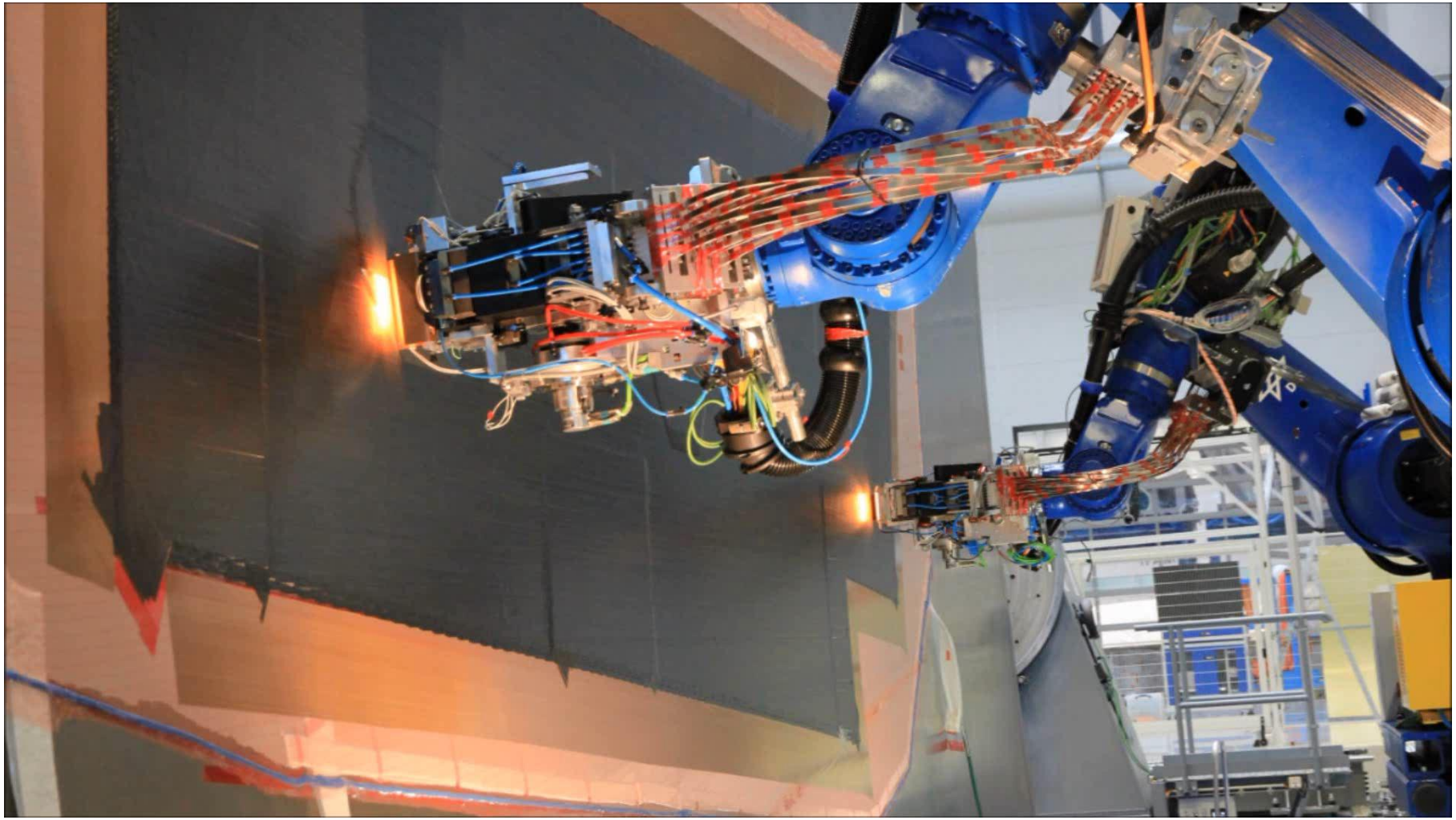
Feedrate / Speed	Value	
On-Surface (non 0°)	30	m/min
On-Surface (0°)	25	m/min
Off-surface	60	m/min
Cut on the fly	8	m/min





DLR MultiHead-Approach

MultiHead Demonstrator - Impressions



DLR MultiHead-Approach

Results – Simulation Validation

Two Step Analysis

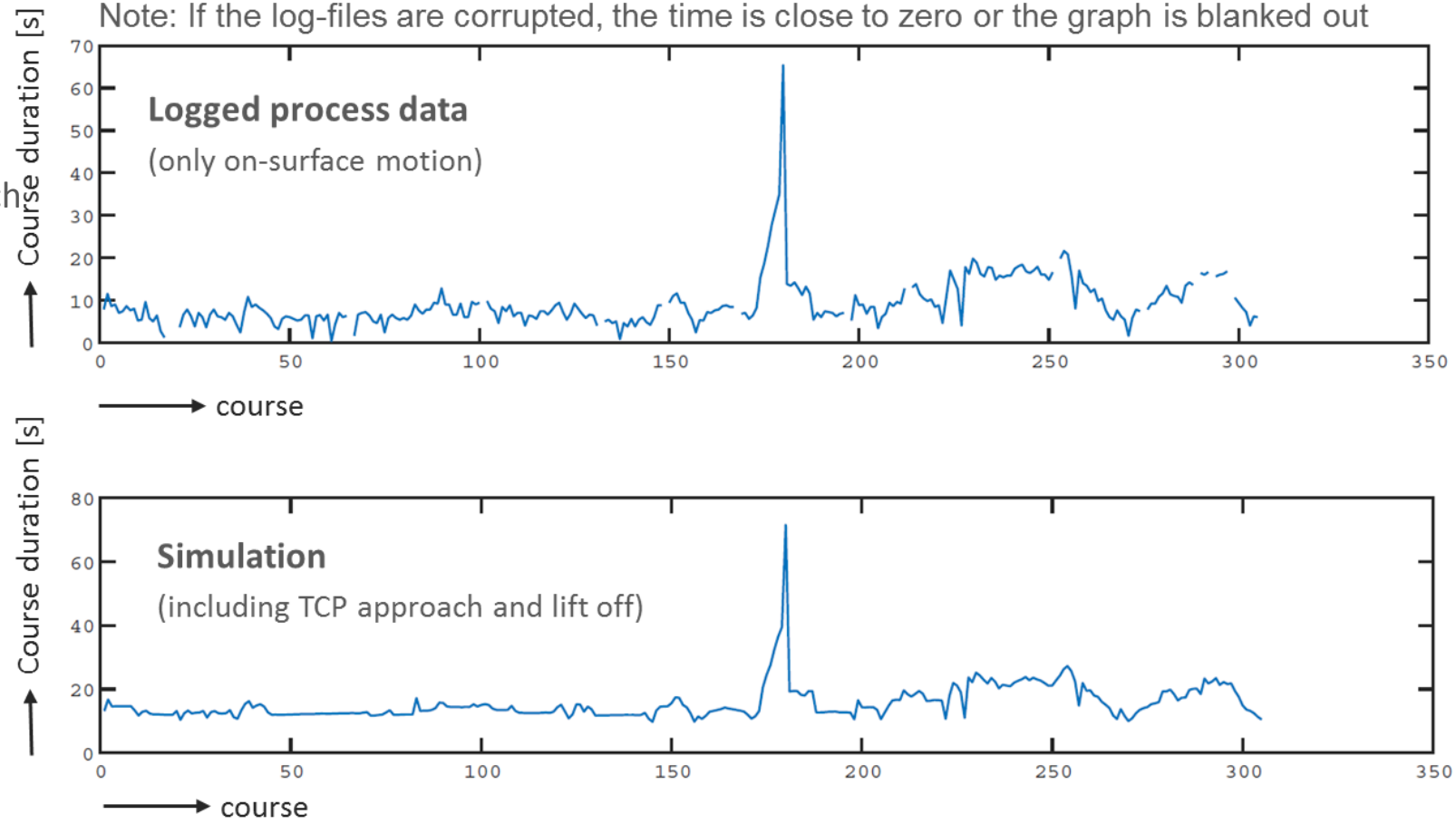
i. Simulation Validation

ii. Improvements of the MulitHead Apporach (regarding the 8m generic wing cover)

Simulation Validation

Simulation Constraint	Value
Average velocity for off-surface movements	0.7 m/s

Note: If the log-files are corrupted, the time is close to zero or the graph is blanked out



Representative subsection of the MH-demonstrator (12Plies)

DLR MultiHead-Approach

Results – Simulation Validation

Two Step Analysis

i. Simulation Validation

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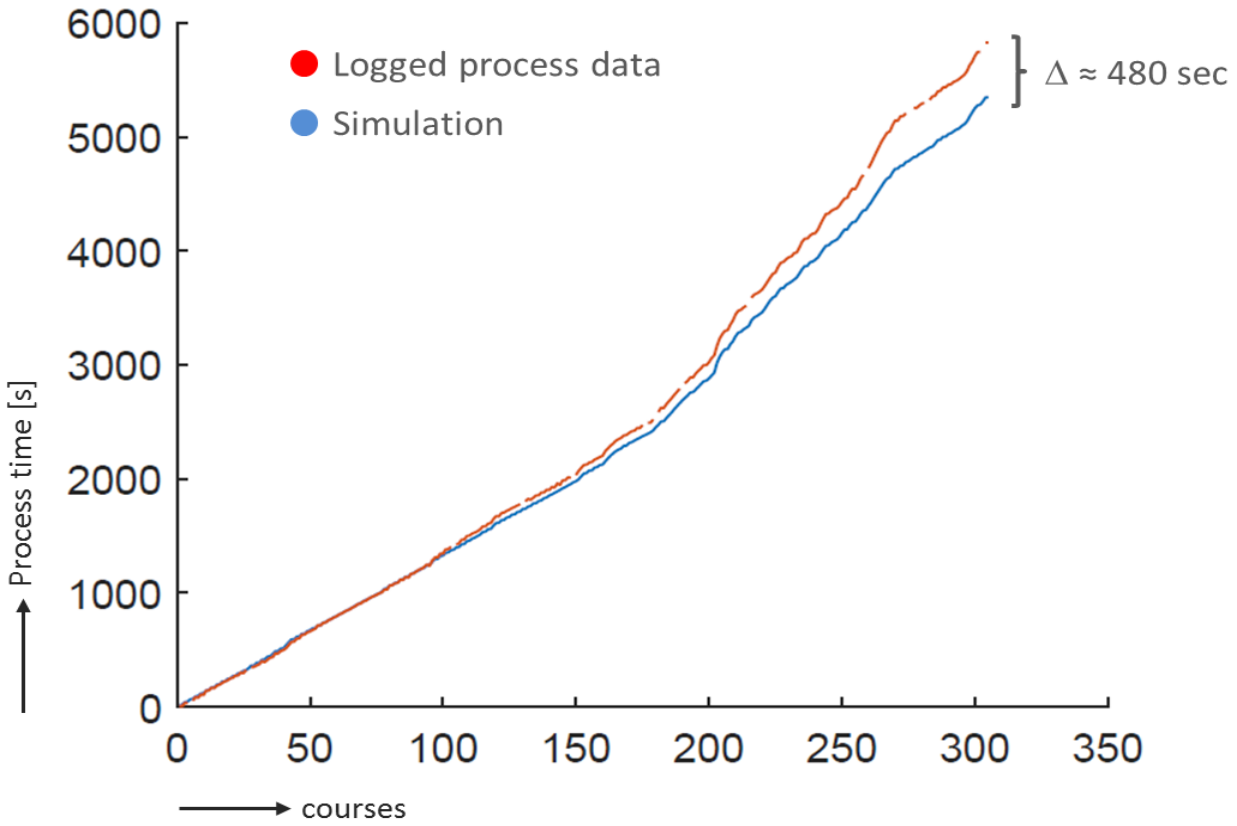
Simulation Validation

Simulation Constraint	Value
Average velocity for off-surface movements	0.7 m/s

→ **Movement behaviour of the layup units is well reflected**

→ **Less than 2% Variance**

Representative subsection of the MH-demonstrator (12Plies)



Overall Variance	480s
Additional safety aspects (not represented by the simulation)	410s
Actual variance	**70 s**

DLR MultiHead-Approach

Results – Simulated Improvements

Two Step Analysis

i. Simulation Validation

ii. Improvements of the MulitHead Apporach (regarding the 8m generic wing cover)

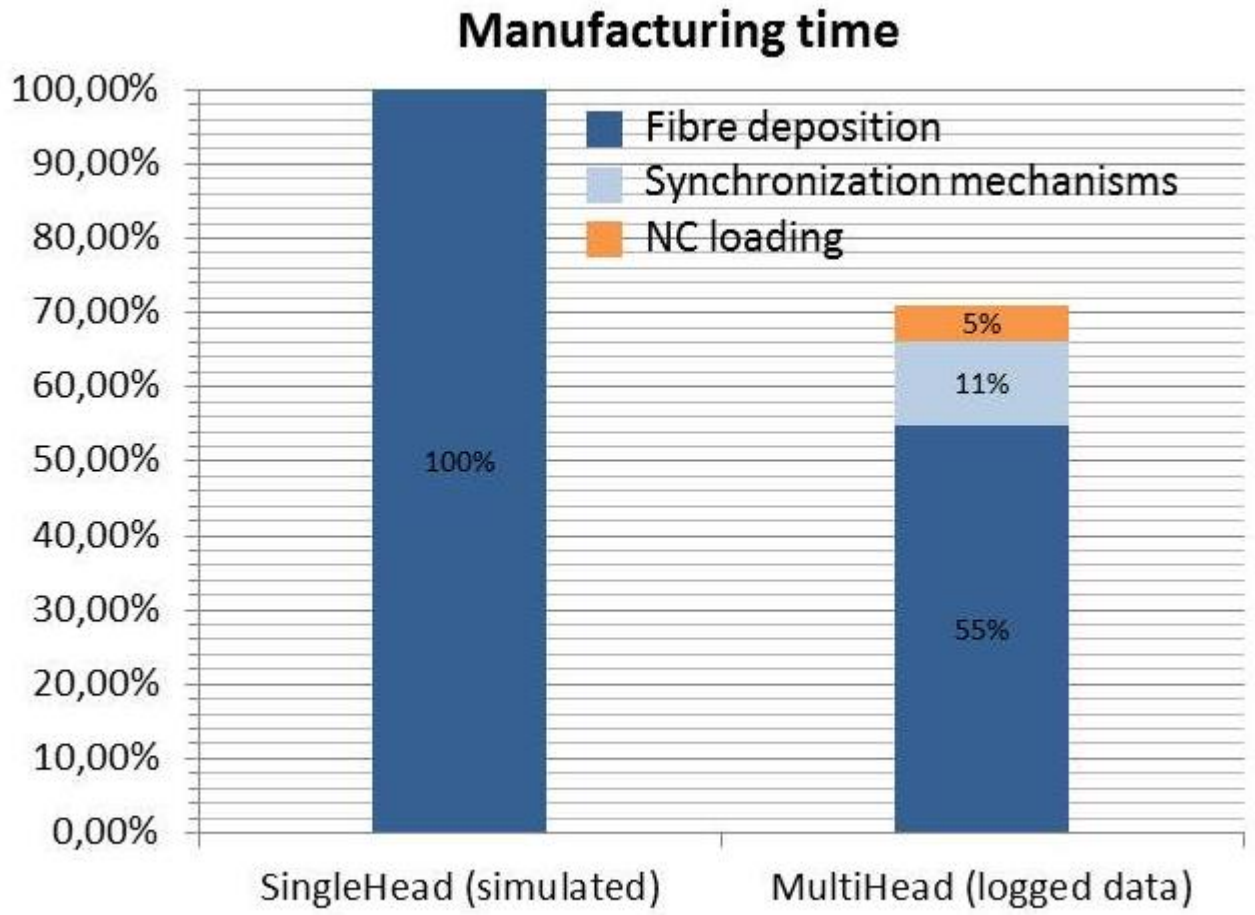
Comparison

- MultiHead (2 units) vs. SingleHead
- Regardiung the entire manufacturing process

→ **Fiber deposition: 45% time saving**

→ Synchronization: Additional safety
Can be reduced in future processes

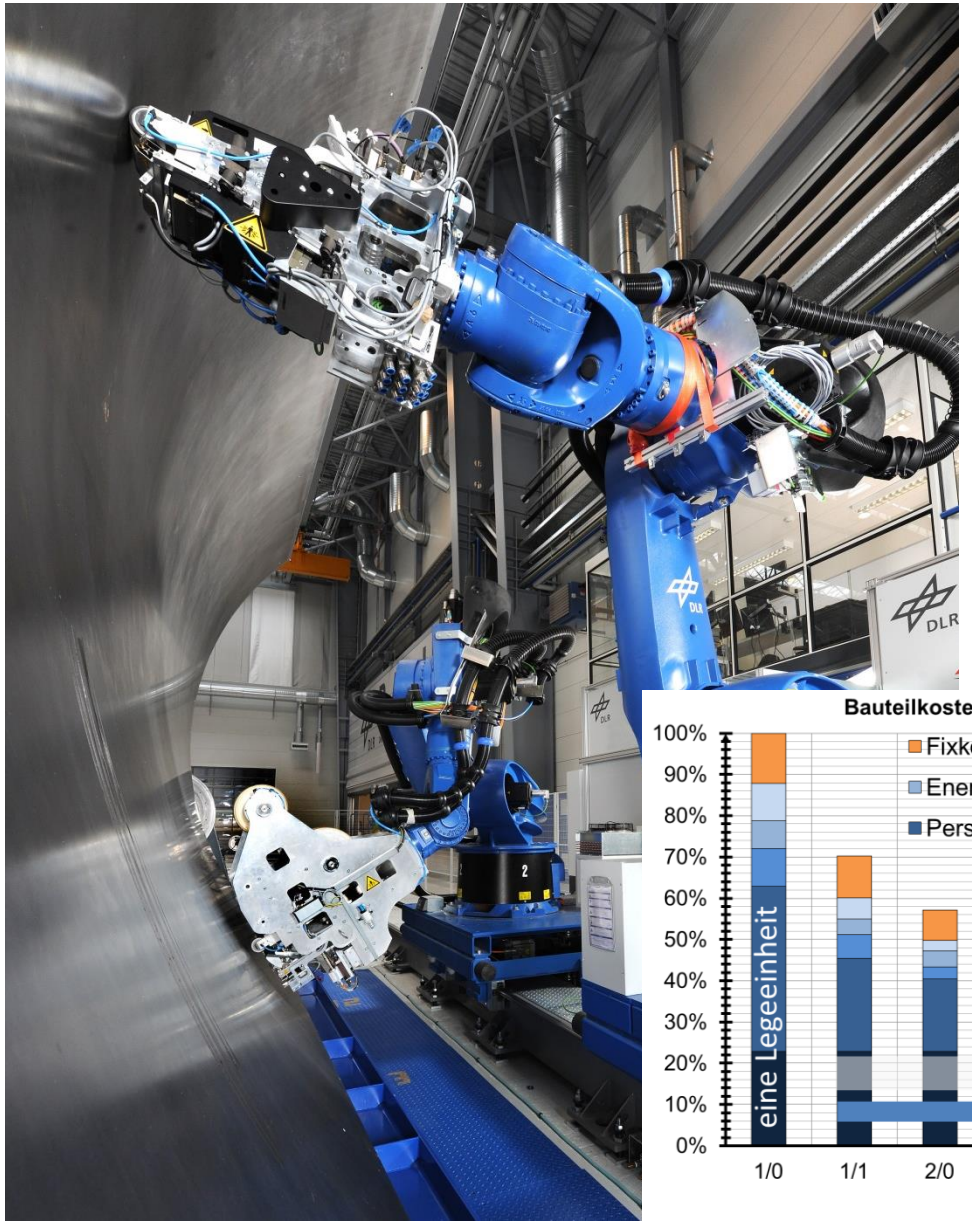
→ NC loading: Due to the data structure of the GroFi research platform. Can be optimized for industrial use

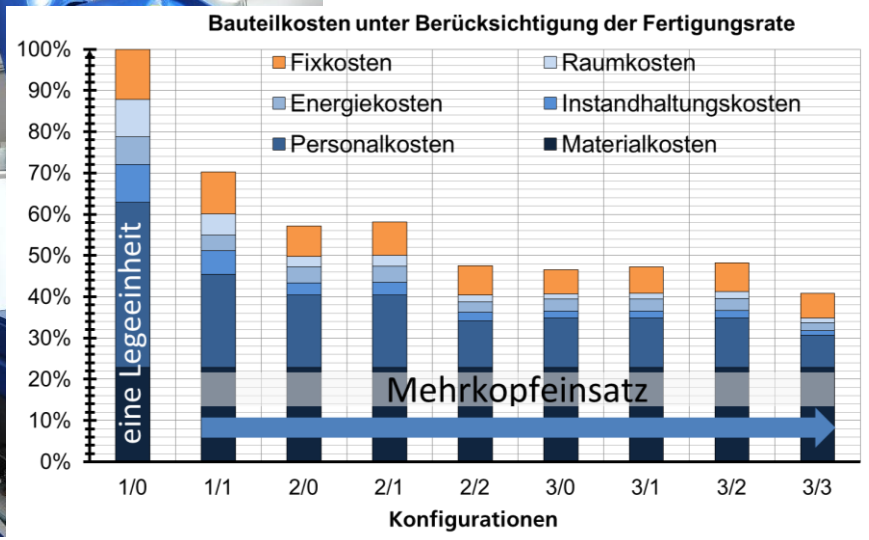


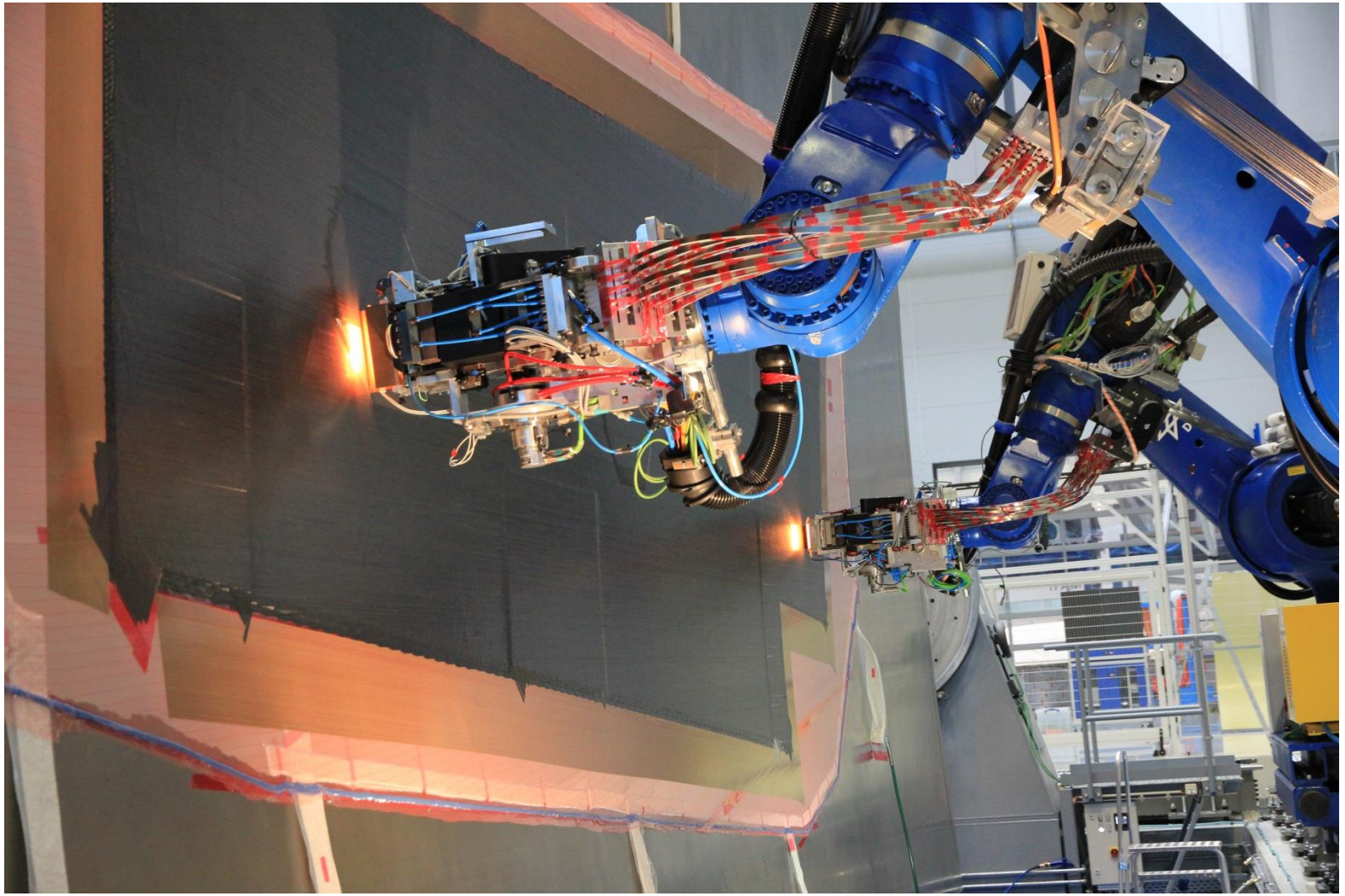
DLR MultiHead-Approach

Outlook

- **Online (re-) scheduling**
- **Production scheduling considering the whole complexity of the GroFi plant**
- Manufacturing process of **n parts using m layup units**
- **Multi-technology processes**
- **Part adapted plant design**
  Calculation and comparison of different plant designs







Thank you!

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Gefördert durch:

Bundesministerium für Wirtschaft und Energie

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